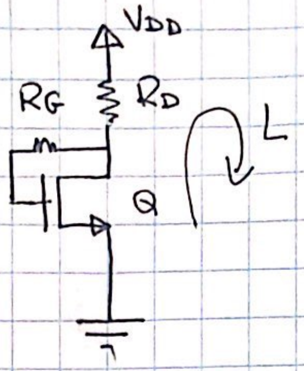
ECE 322L - SPRING 2020

LECTURE 4 - PROBLEM 1



$I_D = 0.5\,mA \quad V_{DD} = 5V \quad R_G = 1M\Omega$

$K_n' \frac{W}{L} = 1\,mA/V^2 \quad V_{TN} = 1V \quad \lambda = 0$

$R_D = ?\ ;\ I_{D,ACT} = ?\ ;\ V_{D,ACT} = ?$

$V_G = V_D \Rightarrow V_{GS} = V_{DS} \Rightarrow V_{DS} > V_{GS} - V_T$. Thus Q is in saturation.

KVL @ loop L:

$V_{DD} - R_D I_D - V_{DS} = 0$

$R_D = \frac{V_{DD} - V_{DS}}{I_D}$

$R_D = \frac{V_{DD} - V_{GS}}{I_D}$

$I_D = \frac{1}{2} K_n' \frac{W}{L} (V_{GS} - V_{TN})^2 \Rightarrow (V_{GS} - V_{TN})^2 = \frac{0.5m \cdot 2}{1m} = 1V$

$(V_{GS} - V_{TN}) = \pm 1 \Rightarrow V_{GS} \begin{cases} 0V \\ 2V \end{cases}$

$V_{GS} = 0$ will be discarded as it is lower than the threshold voltage. $I_D = 0.5\,mA$ hence, the transistor cannot be in cut-off.
We select
$V_{GS} = 2V$

$R_D = \frac{V_{DD} - V_{GS}}{I_D} = \frac{5 - 2}{0.5m} = 6\,K\Omega$

We select $R_D = 6.2\,K\Omega$ among the list of 5% resistor values.

Now, let's calculate $I_{D,ACT}$ and $V_{D,ACT}$.

$$I_D = \frac{1}{2} \cdot 1m\,(V_{GS}-1)^2 \qquad V_{GS} = V_{DD} - R_D I_D$$

$$I_D = \frac{1}{2} m\,(V_{DD} - R_D I_D - 1)^2$$

$$I_D = \frac{1}{2} m\,(4 - 6.2K\,I_D)^2$$

$$38.44\,I_D^2 - 51.6\,I_D + 16 = 0 \rightarrow I_D \begin{cases} 0.49mA \\ 0.86mA \end{cases}$$

- For $I_D = 0.86\,mA$, $V_{GS} = V_{DD} - R I_D \Rightarrow V_{GS} = 5 - 6.2K \cdot 0.86m$

$V_{GS} = 5 - 5.33 = -0.33V$

$V_{GS} < V_T$ Q is in cut-off for $V_{GS} = -0.33V$. As the required $I_D = 0.5mA$, Q can't be in saturation.

- For $I_D = 0.49mA$, $V_{GS} = 5 - 6.2K \cdot 0.49m = 1.96\,V$

$V_{GS} > V_{TN}$

$I_{D,ACT} = 0.49mA$

$V_{D,ACT} = 1.96V$

LECTURE 4 - PROBLEM 2

$\frac{L_2}{L_1} = 1 \quad \frac{W_2}{W_1} = 5 \qquad I = I_{D2} = 0.5\, mA \qquad V_{DD} = -V_{SS} = 5V$

$K_n' \left(\frac{W}{L}\right)_1 = 0.8\, mA/V^2 \qquad V_{TN} = 1V \qquad \lambda = 0 \qquad R = ?$

$V_{G_{1,2}} = ?$

$I = I_{REF} \frac{(W/L)_2}{(W/L)_1} = I_{REF} \cdot \frac{W_2}{W_1} \Rightarrow I_{REF} = I \cdot \frac{W_1}{W_2} =$

$= \frac{0.5m}{5} = 0.1\, mA.$

$I_{REF} = \frac{V_{DD} - V_G}{R} \Rightarrow R = \frac{V_{DD} - V_G}{I_{REF}}$

$V_{GS_1} = V_{DS_1} \Rightarrow Q_1$ is in saturation. Thus

$I_{D1} = I_{REF}$

$I_{REF} = \frac{K_n'}{2}\left(\frac{W}{L}\right)_1 (V_{GS_1} - V_{TN})^2 \Rightarrow (V_{GS_1} - V_{TN})^2 = \frac{0.1 \cdot 2}{0.8}$

$V_{GS_1} - V_{TN} = \pm 0.5 \Rightarrow V_{GS_1}$
- 1.5V (Select as it is larger than V_{TN})
- 0.5V (Discard as it is lower than V_{TN})

$V_G = V_{SS} + V_{GS_1} \Rightarrow V_G = V_{SS} + V_{GS} = -5V + 1.5 = -3.5V$

$R = \frac{5 - (-3.5)}{0.1m} = 85\, k\Omega$

$V_{D_{2\,min,SAT}} = V_{SS} + V_{DS_{1,SAT}} \; ; \; V_{DS_{2,1}SAT} = V_{GS_2} - V_{TN}$

$V_{GS2} = V_{GS_1} = 1.5V \Rightarrow V_{DS_{2,SAT}} = 1.5 - 1 = 0.5V$

$V_{D_2\,min,\,SAT} = -5 + 0.5 = -4.5V$